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WHISTLER-MODE PROPAGATION STUDIES USING NAVY VLF TRANSMITTERS

R. A. Helliwell
Principal Investigator

May 1967

FINAL REPORT

Prepared under
Office of Naval Research
Contract Nonr-225(27)

RADIOSCIENCE LABORATORY
STANFORD ELECTRONICS LABORATORIES
STANFORD UNIVERSITY · STANFORD, CALIFORNIA

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Final Report Nonr 225(27)
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I. IN ODUCTION

The purpose of this report is to review the work carried out under the Office of Naval Research contract Nonr 225(27) covering the period July 1, 1956 to June 30, 1966. The review is organized under five main topics: 1) whistler-mode propagation studies using controlled sources; 2) wave-particle interactions; 3) correlation of unique vlf propagation characteristics with other geophysical phenomena; 4) development of a vlf transmitting research facility in Antarctica; and 5) international cooperative programs. At the end of the report is a list of papers presented at scientific meetings and papers published in report or journal form.

It would be appropriate at this time to review briefly some of the contributions that past work carried out with station NSS in 1957 has made to magnetospheric research. During this work the first controlled test giving support to Storey's theory of the path of whistlers was made. It provided a new technique for the systematic study of magnetoionic duct propagation and the exploration of the magnetosphere.

One of the results of a study of the characteristics of whistlers was that on many occasions whistlers triggered vlf emissions. Extension of this study to man-made vlf signals propagating in the magnetosphere revealed that vlf emissions are often triggered by the transmissions from NPG and NAA.

In addition to the specific results mentioned above, past work with Navy vlf stations has contributed in many ways to improvements in our general understanding of vlf propagation.

II. REVIEW OF WORK

A. Whistler-Mode Propagation Studies Using Controlled Sources

After successful completion of the 1957 whistler-mode tests using special transmissions from NSS, a request was submitted to the Office of the Chief of Naval Operations to provide long term special transmissions on NSS, NPG, NPM, and later on NAA. The U. S. Navy kindly provided the special transmissions and the resultant high quality data added significantly to our understanding of propagation in the whistler-mode.

Since broadband whistler measurements were made during the periods of the special transmissions (fixed-frequency), the following new results were observed:

(1) Day-to-day whistler-mode activity varies widely, suggesting that activity might be controlled either by the trapping ability of the magnetospheric ducts or by the horizontal gradients of ionization in the F region.

(2) Frequent absence of whistlers when fixed-frequency echo activity is high confirms the expectation that the whistler-rate is affected significantly by thunderstorm activity.

(3) The observation of whistlers when no fixed-frequency echoes are observed suggests the presence of a variable high-frequency cutoff in whistler-mode propagation.

(4) Group delays are reduced during magnetic storms and are lower in June than in December, which is in accord with whistler data.

B. Wave-Particle Interactions

The discovery of the triggering of vlf emissions in the

magnetosphere by whistler-mode signals transmitted from vlf stations operated by the U. S. Navy was not a direct result of the work funded by this contract, but the fact that this phenomena was observed so early in our program history was due to the emphasis placed on the use of controlled sources. That is to say, the interaction processes observed in association with whistlers were searched for, with success, in the fixed-frequency echo data.

The unique features of the artificially stimulated emissions are providing invaluable information to workers involved in theoretical studies of the mechanism of vlf emission generation.

C. Correlation of Unique VLF Propagation Characteristics with Other Geophysical Phenomena

The field intensity of the ground wave of several vlf transmitters was measured on a continuous basis at Stanford, California; Quebec City, Canada; Byrd Station, Antarctica; and Eights Station, Antarctica. These data were used to determine the diurnal behavior of the received vlf signals and to determine the effects of solar flares, sunrise, sunset, etc. on these signals. These measurements were made in order to separate the effects of the earth-ionosphere waveguide from those in the magnetosphere.

Since these data were available on a continuous basis it was proposed to study the amplitude anomalies evident in the data in an attempt to correlate them with other geophysical phenomena being measured. This investigation turned up two very interesting correlations. The first was between the fluctuations in the intensity of vlf signals and micropulsations, and the second was between mid-latitude nighttime vlf signal

intensity and magnetic bays. The latter was quite significant since an auroral event at high latitudes affected the nighttime propagation of vlf signals whose paths were entirely in the mid-latitudes.

D. Development of a VLF Transmitting Research Facility in Antarctica

It was stat d earlier that vlf emissions can be generated by artificial as well as by natural signals. In addition it was found from whistler studies that the optimum frequency range for triggering emissions is 2.0 kHz to 6 kHz. Since no operational transmitter was available in early 1964 that could transmit in this frequency range, a request for such a transmitter was submitted to Dr. A. Shostak of the Office of Naval Research.

A vlf transmitter whose power, frequency, and modulation could be controlled over the frequency range 2 kHz to 30 kHz was loaned to Stanford University by the Office of the Chief of Naval Operations. This unit was installed near Byrd Station, Antarctica in February 1965 in a new station provided by the Department of the Navy and the National Science Foundation, and has been operational since that time.

E. International Cooperative Programs

Although it was not anticipated in the early years of our research under this contract that assistance would be provided to laboratories in other countries, this in fact has happened. A complete whistler receiving station procured under this contract for use at Greenbank, West Virginia, but not longer needed there was transferred to the Ionospheric Institute of the University of Athens in Greece. Even though members of the Institute are relatively inexperienced in

the study of the whistler-mode, their analysis and interpretation of the data acquired could prove to be meaningful.

We have had a long and successful cooperative program with the New Zealand Department of Scientific and Industrial Research. The special transmissions provided by the U. S. Navy on NPG and NPM have been utilized with great success by D.S.I.R. and have enabled them to make valuable contributions to our knowledge of whistler-mode propagation.

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13. ABSTRACT

The review is organized under five main topics: 1) whistler-mode propagation studies using controlled sources; 2) wave-particle interactions; 3) correlation of unique vlf propagation characteristics with other geophysical phenomena; 4) development of a vlf transmitting research facility in Antarctica; and 5) international cooperation.

The history of using a controlled source as a tool for investigating the magnetospheric medium is reviewed. This technique has proven quite successful and will play a significant role in the future studies of whistler-mode propagation and environment modification.

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